# Factors affecting *Campsis radicans* seed germination and seedling emergence

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The effects of environmental factors on germination and emergence of *Campsis rad*icans seeds were examined in laboratory and greenhouse experiments. Campsis radicans pods produced numerous, papery, and small seeds (696 seeds/pod; 4 mg/seed). Seeds exhibited dormancy that was relieved (74% germination) after 2 wk of prechilling. Fluctuating temperatures and a 12-h photoperiod were required for maximum germination. Optimum conditions for *C. radicans* seed germination (74%) were 35/25 C (day/night, 12/12 h) with a 12-h photoperiod. Temperatures below 25/15 C or above 40/30 C were unfavorable for germination. Germination in constant temperatures or in continuous darkness was less than 15%. More than 59% of C. radicans seeds germinated at pH 5 to 9, but at pH 4 or 10 seed germination was totally inhibited. Germination was totally inhibited at osmotic stress higher than -0.2 MPa. Germination was 60% at 40 mM NaCl and 20% at 160 mM NaCl. Emergence was maximum (68%) for seeds that were placed on the soil surface, but no seedlings emerged from a soil depth at 4 cm. About 10% of seeds were still viable even after 20 wk of prechilling. Each pod contained about 700 seeds and each plant produced 20 to 40 pods. These results suggest that the spread potential of C. radicans by seeds would be at least 1,400 to 2,800 seeds plant<sup>-1</sup>. However, only seeds near the soil surface would be able to germinate.

Nomenclature: Trumpetcreeper; Campsis radicans (L.) Seem. ex Bureau CMIRA.

**Key words:** Osmotic potential, pH, photoperiod, planting depth, salt stress, temperature, CMIRA.

Campsis radicans (L.) Seem. ex Bureau (trumpetcreeper) is a common perennial vine found in the Mississippi Delta and also in reduced-tillage fields in the northcentral United States. Campsis radicans is found in cultivated fields, wastelands, fence rows, and riverbanks and is extensively distributed in the southern United States. The plant is a deciduous, woody dicot, shrubby vine capable of growing several meters in length. Campsis radicans is among the 10 most troublesome weeds in cotton and soybean (Dowler 1998). Campsis radicans is difficult to control because of its extensive deep root system (Elmore 1984). The plant usually does not produce seeds in cultivated areas, although the authors have occasionally seen plants flowering in poorly managed fields. Propagation is mostly vegetative, but this species produces numerous fruit in noncultivated areas such as ditches, roadsides, and fence rows. The fruit is a long, two-celled, flattened, capsule that contains numerous seeds with an outer thin, papery wing that surrounds the embryo and flat round cotyledons (Bonner 1974). The small, flat, winged seeds are dispersed chiefly by wind as the mature capsules split open on the vine from October through December (Bonner 1974).

Several environmental factors are known to affect weed seed germination. The optimum temperature, light, and pH conditions vary considerably depending on the species (Egley and Duke 1985; Taylorson 1987). Weed seedling emergence has been reported from a wide range (0 to 15 cm) of soil depths (Balyan and Bhan 1986; Singh and Achhireddy 1984). There is little published information about *C. radicans* seed germination and seedling establishment. An understanding of germination and emergence of

*C. radicans* seeds would help to predict its potential spread into new areas and would be useful in developing effective control measures. The objectives of this study were to (1) characterize *C. radicans* seed production and (2) determine the effect of light, temperature, planting depth, pH, osmotic stress, and salt stress on seed germination and emergence.

#### **Materials and Methods**

#### **General Information**

Campsis radicans pods were collected in the fall of 1998 from plants growing along roadsides and wastelands near the Southern Weed Science Research Unit farm in Stoneville, MS. Seeds were removed from pods and stored at  $5\pm2$  C until used.

Twenty-five seeds were placed on Whatman filter paper<sup>1</sup> in a 9-cm plastic petri dish. The filter paper was moistened with 5 ml distilled water or test solution. Petri dishes were wrapped with parafilm<sup>2</sup> then placed inside transparent self-sealed plastic bags to minimize water losses from evaporation. Germination was determined by visible radicle protrusion 2 wk after incubation. Germinated seeds were removed from petri dishes, and the ungerminated seeds were left for another 2 wk, where no further germination was observed. The tetrazolium chloride test was used to test viability of the ungerminated seeds (ISTA 1985).

#### **Seed Characteristics**

Forty pods were randomly selected. In each pod, the length, thickness in the middle of the pod, pod fresh weight,

total fresh seed weight, and fresh weight of 100 seeds were measured. Fresh weight of 100 seeds was determined from the average of three replications of 100 seeds  $pod^{-1}$ . Total seed number per pod was calculated by dividing the total fresh seed weight per pod by the average fresh seed weight. Seed moisture content was determined by the hot oven method at  $103 \pm 2$  C for 17 h (ISTA 1985). Four samples each of 100 seeds were used to determine seed moisture, which was calculated on a fresh weight basis.

# **Temperature and Light**

Germination was determined in growth chambers under constant (20, 25, 30, and 35 C) or fluctuating temperatures (day/night temperatures: 25/15, 30/20, 35/25, 40/30 C). Photoperiod was set at 12 h to coincide at high temperature. Fluorescent lamps were used to produce a photosynthetic photon flux density of 200  $\mu mol~m^{-2}~s^{-1}.$  To study seed germination in the dark, a set of petri dishes was wrapped in a double layer of aluminum foil. Seeds with or without prechilling (explained below) were used.

# **Prechilling**

Because germination of untreated seeds was low, prechilling was applied to break dormancy. Prechilling is described as the exposure of seeds to cold and moist conditions for the required period (Bewley and Black 1982). Seeds were placed between two layers of paper towels moistened with distilled water then placed inside self-sealed plastic bags. Samples were subsequently stored in a refrigerator (5  $\pm$  2 C) for 1, 2, 4, 8, 12, 16, and 20 wk. Germination was determined after the prechilling period in all treatments. Germination tests were performed as described above. In all subsequent experiments, seeds prechilled for 2 wk were used since the highest germination percentage was achieved by this duration of prechilling.

#### **Planting Depth**

Fifty prechilled seeds were planted in soil in 15-cm-diam plastic pots at depths of 0, 0.5, 1, 2, and 4 cm. Soil used was a Bosket sandy loam (fine-loamy, mixed, thermic Mollic Hapludalfs). Greenhouse temperatures were  $35 \pm 4$  C during the day and  $25 \pm 5$  C during the night. Natural light was supplemented with sodium vapor lamps to provide 14 h of light. Pots were watered as needed to maintain adequate soil moisture. Emergence was defined as the appearance of the two cotyledons 4 wk after planting.

# pН

The effect of pH on germination was studied using buffer solutions of pH 4 to 10 prepared as described for *Bidens pilosa* (hairy beggarstick) seeds (Reddy and Singh 1992). A 2-mM potassium hydrogen phthalate buffer solution was adjusted to pH 4 with 1 N HCl. A 2-mM solution of MES [2-(*N*-morpholino)ethanesulfonic acid] was adjusted to pH 5 or 6 with 1 N NaOH. A 2-mM solution of HEPES [*N*-(2-hydroxymethyl)piperazine-*N*-(2-ethanesulfonic acid)] was adjusted to pH 7 or 8 with 1 N NaOH. A pH 9 or 10 buffer was prepared with 2-mM tricine [*N*-tris(hydroxymethyl) methylglycine] and adjusted with 1 N NaOH. Unbuffered

deionized water (pH 5.6) was used as a control. Petri dishes were incubated at 35/25 C day/night temperature with 12 h light as described in the temperature and light study. Results of temperature and light studies indicated that maximum germination was obtained when seeds were incubated at the above conditions. Twenty-five prechilled seeds per petri dish were used and replicated four times.

#### Osmotic and Salt Stress

Aqueous solutions with osmotic potential of 0, -0.05, -0.10, -0.20, -0.40, and -0.80 MPa were prepared by dissolving appropriate amounts of polyethylene glycol (PEG) 8000 in deionized water (Steuter et al. 1981). Petri dishes were incubated as described in the temperature and light study.

Sodium chloride solutions of 0, 10, 20, 40, 80, and 160 mM were prepared. Petri dishes were incubated as described in the temperature and light study.

# **Statistical Analysis**

A randomized complete block design with four replications was used in all experiments. Experiments were repeated twice. The data represent the average of the two experiments since no experiment by treatment interaction was revealed. In all experiments, percent germination data were transformed using the  $\log(x+1)$  transformation, where x is percent germination. Transformation of data was needed only in planting depth and salt stress experiments. In these experiments, however, regression analysis was more appropriate for the data. In all other experiments, nontransformed data were presented. Means were separated using Fisher's protected LSD test at P=0.05.

### **Results and Discussion**

#### **Seed Characteristics**

The average length of *C. radicans* pods was  $16 \pm 0.5$  cm and the average fresh weight was  $7 \pm 0.5$  g pod<sup>-1</sup>. Each pod contained on average  $696 \pm 48$  seeds with a moisture content of  $7.3 \pm 0.04\%$ . The average weight of 100 seeds was  $0.39 \pm 0.02$  g. *Campsis radicans* produced 20 to 40 pods plant<sup>-1</sup> (Chachalis and Reddy, unpublished data); therefore, *C. radicans* has the potential to spread into new areas because each pod carries a large number of papery seeds that can disperse by wind.

# Effect of Temperature and Light on Non-Prechilled Seeds

Non-prechilled seed germination was low under constant or fluctuating temperatures in both 12-h photoperiod or continuous darkness (Table 1). Maximum germination (17%) occurred at 35/25 C in the 12-h photoperiod. However, seed viability (tetrazolium chloride test) indicated that most seeds (> 90%) were viable (data not shown). Therefore, we concluded that *C. radicans* seeds exhibit dormancy.

#### **Prechilling**

Prechilling for 1 or 2 wk increased *C. radicans* seed germination (55 and 70%, respectively, Figure 1). Seeds pre-

Table 1. Effect of constant or fluctuating temperatures (day/night, 12/12 h) on germination of *C. radicans* seeds incubated in the dark or with a 12-h photoperiod for 2 wk. Seeds used with or without prechilling (moist,  $5 \pm 2$  C) for 2 wk.

	No prechilling			Prechilled for 2 wk		
Temperature	Light	Dark		Light		Dark
С			-%-			
20	0	0		0		0
25	3	3		3		3
30	6	4		6		4
35	2	1		15		2
25/15	1	1		3		1
30/20	6	1		44		1
35/25	17	6		74		7
40/30	6	0		15		0
LSD (0.05)	4	2			3	

chilled for periods longer than 2 wk germinated less than 9%, and most were dead (data not shown). It appeared that 2 wk of prechilling breaks the dormancy but that prechilling for longer periods leads to seed decay. Seed dormancy is viewed as an essential survival mechanism extending seed viability (Egley and Duke 1985). Our prechilling results, however, suggest that most C. radicans seeds would lose viability due to seed decay if exposed to cold and moist conditions for more than 2 wk. Whether similar results will be obtained in soil under field conditions is not known. We are currently investigating the effect of natural exposure of pods and seeds in soil during the winter on seed germination and viability as part of an on-going dormancy study. Results of this study indicated that about 10% of seeds were still viable even after 4 mo of prechilling. Since each pod of C. radicans contains about 700 seeds and each plant produces 20 to 40 pods, 1,400 to 2,800 seeds plant<sup>-1</sup> could survive after overwintering. Furthermore, we have observed that some pods do not split open in fall; these pods would gradually lose their integrity and eventually split open at a time that might coincide with favorable conditions for seed germination. It is possible that seeds remain protected inside the pods during winter exposure. If this is the case, the spread potential of C. radicans by seeds would be even greater than 1,400 to 2,800 viable seeds plant<sup>-1</sup>.

# **Effect of Temperature and Light on Prechilled Seeds**

Even after seeds were released from dormancy, both fluctuating temperatures and 12-h photoperiod were required for optimum germination (Table 1). Our results clearly show that 2 wk of prechilling did not overcome the light requirement for germination of *C. radicans* seeds. Similar results have been reported for *Scoparia dulcis* (goatweed, Jain and Singh 1989), whereas prechilling overcame the light requirement in *Senecio vulgaris* (common groundsel, Popay and Roberts 1970). *Campsis radicans* germination was highest at 35/25 C (74%), followed by 30/20 C (44%), at the 12-h photoperiod. Germination was decreased (< 15%) above and below these ranges. The optimum temperatures for *C. radicans* seed germination coincide with the typical late spring and summer temperatures in the Mississippi Delta region.

Under constant temperatures, germination was less than

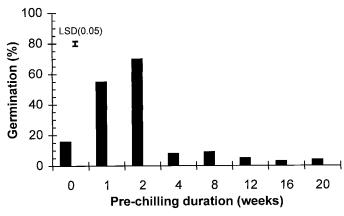


Figure 1. Effect of prechilling duration on germination of  $\it C. radicans$  seeds incubated in 35/25 C in a 12-h photoperiod for 2 wk.

15% regardless of the light conditions (Table 1). Under dark conditions, germination was less than 7% regardless of the temperature regime. The stimulation of seed germination by diurnal temperature fluctuation has been reported in many weed species, including *Sorghum halepense* (johnsongrass, Benech Arnold et al. 1990), Cyperus rotundus (purple nutsedge, Miles et al. 1996), and Eleusine indica (goosegrass, Nishimoto and McCarty 1997). A light requirement for weed seed germination is common (Egley and Duke 1985), especially in species that have small seeds (Taylorson 1987). Campsis radicans seeds are small (4 mg seed<sup>-1</sup>); hence, they contain only a limited amount of food reserves for germination. Inhibition of germination in the dark prevents germination of seeds that are buried deep in the soil. Seeds would only germinate and seedlings emerge when seeds are buried at or near the soil surface.

#### pH

Campsis radicans seed germination was greater than 60% over a pH range from 5 to 9 (Figure 2). Other weed species have been reported to germinate in a wide range of pH, including Brunnichia ovata (redvine, Shaw et al. 1991), Asclepias syriaca (common milkweed, Evetts and Burnside 1972), and S. dulcis (Jain and Singh 1989). In contrast, seeds of Morrenia odorata (stranglervine, Singh and Achhi-

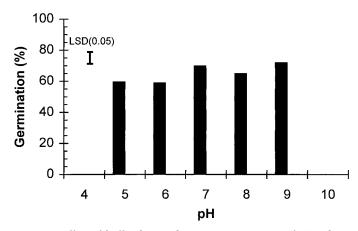


Figure 2. Effect of buffered pH solutions on germination of *C. radicans* seeds prechilled (moist,  $5\pm2$  C) for 2 wk then incubated at 35/25 C in a 12-h photoperiod for 2 wk.

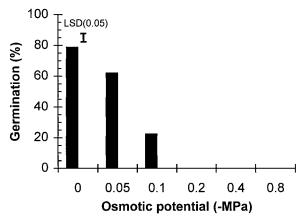


FIGURE 3. Effect of osmotic potential on germination of  $\it C.$  radicans seeds prechilled (moist, 5  $\pm$  2 C) for 2 wk then incubated at 35/25 C in a 12-h photoperiod for 2 wk.

reddy 1984) and *Cirsium arvense* (Canada thistle, Wilson 1979) germinated best between pH 6 to 7. *Campsis radicans* seed germination was totally inhibited only at extreme pH buffer solutions (pH 4 or 10). High seed germination of *C. radicans* over a broad pH range indicates that pH should not be a limiting factor for germination in most soils.

#### **Osmotic and Salt Stress**

Germination of C. radicans seeds was totally inhibited at osmotic stress higher than -0.2 MPa (Figure 3), which indicates that seeds are fairly sensitive to low water potential. As a result, germination and establishment appears to be restricted to well-drained, moist soils because of its inability to germinate under low soil moisture conditions. Similar results have been reported for B. ovata (Shaw et al. 1991) and B. pilosa seeds (Reddy and Singh 1992). However, weed species such as Ampelamus albidus (honeyvine milkweed, Soteres and Murray 1981) and C. arvense (Wilson 1979) tolerate water potential lower than -1.0 MPa.

Germination of *C. radicans* seeds was inversely related to NaCl concentration (Figure 4). Germination was greater than 61% at less than 40 mM NaCl and was lowest (20%) at 160 mM NaCl. These data suggest that even at high soil salinity, a proportion of *C. radicans* seeds may germinate.

#### **Planting Depth**

Emergence of *C. radicans* seedlings decreased rapidly with increased planting depth (Figure 5). Emergence was maximum (68%) for seeds placed on the soil surface, and no seedlings emerged from seeds placed at a depth of 4 cm. These results agree with those of the temperature and light studies (Table 1). *Campsis radicans* seed germination was inhibited in darkness or at constant temperatures. It has been reported that very little light (< 0.001%) is transmitted by any type of soil at a depth greater than 4 mm (Benvenuti 1995). In addition, the magnitude of temperature fluctuation in soils increases near the soil surface and declines in the soil profile (Rubin and Benjamin 1984). In contrast, B. ovata seeds placed on the soil surface did not germinate, whereas > 45% emerge from 5 cm depth (Shaw et al. 1991). Decreased emergence due to increased planting depth has been reported in several weed species, including

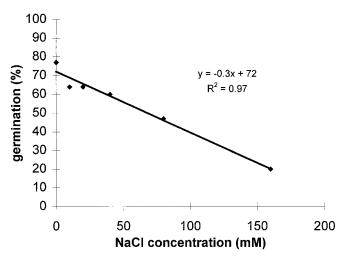


FIGURE 4. Effect of NaCl concentration on germination of *C. radicans* seeds prechilled (moist,  $5\pm2$  C) for 2 wk then incubated at 35/25 in a 12-h photoperiod for 2 wk.

T. portulacastrum (Balyan and Bhan 1986), B. pilosa (Reddy and Singh 1992), M. odorata. (Singh and Achhireddy 1984), and C. arvense (Wilson 1979). These results suggest that under field conditions, no-tillage or minimum-tillage practices would potentially enhance C. radicans seed germination at the soil surface.

# **Summary**

Campsis radicans pods contain many small and papery seeds that could disperse in fall. Seeds exhibit dormancy that was overcome by a 2-wk period of prechilling. However, about 10% of seeds remained viable even after 20 wk of prechilling. Because each pod contains about 700 seeds and some pods may not split open in fall, there are at least 1,400 to 2,800 seeds that could survive after overwintering. Seeds required alternate states of temperature and light to reach optimum germination. Constant temperatures, continuous darkness, or planting seeds below the soil surface reduced seed germination and emergence. High seed germination was recorded with a broad range of pH and salt concentra-

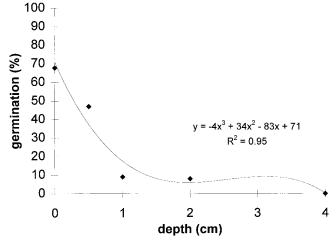


FIGURE 5. Effect of planting depth on germination of  $\it C.$  radicans seeds prechilled (moist,  $5\pm 2$  C) for 2 wk then kept in a greenhouse at 35/25 C with a 12-h photoperiod for 4 wk after planting.

tions, suggesting that germination will not be restricted in most soil conditions. These results suggest that under field conditions, only seeds near the soil surface would germinate.

#### **Sources of Materials**

<sup>1</sup> Whatman #1, Fisher Scientific, 711 Forbes Avenue, Pittsburgh, PA 15219.

<sup>2</sup> Parafilm, American National Company, Greenwich, CT 06836.

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